UNIVERSITY OF NAIROBI
COLLEGE OF ARCHITECTURE AND ENGINEERING
SCHOOL OF ENGINEERING
DEPARTMENT OF ELECTRICAL AND INFORMATION ENGINEERING

PROJECT: SMOKE ALARM

PROJECT NUMBER: 107

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REG. NO: F17/1421/2011

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A project report submitted to the Department of Electrical and Information Engineering in partial fulfilment of the requirements for the award of BSc. Electrical and Electronic Engineering of the University of Nairobi.
DECLARATION OF ORIGINALITY

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COURSE NAME: BSc. Electrical and Electronic Engineering
PROJECT: SMOKE ALARM

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NG’ANG’A RENSON NGOCHI
F17/1421/2011

This report has been submitted to the Department of Electrical and Information Engineering, University of Nairobi with my approval as supervisor:

DR. C. W. Wekesa
Date: .................................................................
DEDICATION
This project is dedicated to my parents, James Ng’ang’a Mwangi and Martha Wamaitha Ng’ang’a and my siblings, Catherine Nyambura, Martin Mwangi and Caroline Wairimu for their unwavering financial and emotional support as well as undying love and encouragement throughout my academic journey.
ACKNOWLEDGEMENT
First, I would like to thank the Almighty God for granting me life and good health as well as supreme protection and guidance throughout my studies.

I am thankful to my supervisor, Dr. C. W. Wekesa for his informative and useful guidance and suggestions throughout the journey for project design.

I am very grateful to the Department of Electrical and Information Engineering and my lecturers for instilling in me the knowledge that has brought me this far.

I am thankful to my friends and classmates who have contributed to the success of my studies through their wise counsel and support.

Needless to mention, this project would not have been complete without reference to and inspiration from the work of others whose details are included in the reference section of this document.
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CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

A smoke alarm is a device that senses smoke, typically as an indicator of fire. It may issue a signal to a fire alarm control panel as part of fire alarm system, especially in commercial security devices or may issue a local audible or visual alarm in the household [1].

Fire detection has become a crucial aspect in design of buildings, both commercial and domestic, as opposed to about 70 years ago when automatic detection was rarely provided in buildings. Before introduction of smoke and fire alarms, fires resulted in the loss of human lives and damage of property and it was mainly attributed to lack of a mechanism for early detection of fire. Early developments in design of smoke alarm began in 1922 with observations by Greinacher and later by Walter Jaeger in 1930. However, early smoke detectors required high voltage power input. Further research was done and power requirement in smoke detectors was reduced to make battery power viable and this made widespread installation in residences highly feasible. Later developments in smoke detectors have sought to improve their performance, reduce power requirement, improve their nuisance alarm sensitivity and also to continuously monitor their status. The most recent advances in smoke detectors have been motivated to make them ‘smarter’ [2].

Smoke can be detected either optically (photoelectric) or by physical process (ionization). Detectors may use either or both methods.

Smoke detectors have prior detection when compared with heat detectors, hence are preferred for fire detection. They also find application in detecting, and thus deter smoking in premises where it is banned.
1.2 PROBLEM STATEMENT
Safety is a crucial consideration in design of residential and commercial buildings in order to safeguard against loss of life and damage to property. Fire is a key element in safety considerations.

This project therefore seeks to design a microcontroller based smoke alarm that will continuously monitor the presence of significant amount of smoke and activate an alarm to prompt a safety measure to contain the situation. There is also an extra functionality of LCD display for visual alert.

1.3 OBJECTIVES
The main objective of this project is to design a circuit useful for detecting smoke and activating an alarm. To achieve this, the following must be done:

a) Analysis and calibration of MQ2 smoke sensor.

b) Development of program to convert the analog output of the sensor to equivalent digital form in the microcontroller.

c) Development of visual warnings (LCD and LED) to indicate smoke detection.

d) Development of audio warnings (buzzer) to indicate the presence of smoke.

1.4 SCOPE OF WORK
The scope of this project is to design a circuit for smoke detection. It activates an alarm when a substantive quantity of smoke is sensed. Hence, it does not primarily indicate the presence of fire.
CHAPTER 2: LITERATURE REVIEW

A smoke detector is a device that senses smoke typically as an indicator of fire or non-smoking zone.

In order to ensure human safety and safeguard property against fire in both domestic and commercial settings, different solutions for smoke detection have been developed. These designs vary depending on the method of smoke detection. However, the different designs are derived from the two basic types of smoke detectors, namely: 1. The photoelectric smoke detector

2. The ionization chamber smoke detector (ICSD)

The photoelectric smoke detector uses an optical beam to search for smoke. When smoke particles cloud the beam, a photoelectric cell senses the decrease in light intensity and triggers an alarm. This type of smoke detector reacts most quickly to smoldering fires that release relatively large amounts of smoke.

On the other hand, the ionization chamber smoke detector is quicker at sensing flaming fires that produce little smoke. It employs a radioactive material to ionize the air in a sensing chamber; the presence of smoke affects the flow of the ions between a pair of electrodes, which triggers the alarm [3]. In a typical system, the radioactive material emits alpha particles that strip electrons from the air molecules, creating positive oxygen and nitrogen ions. The electrons attach themselves to other air molecules, forming negative oxygen and nitrogen ions. Two oppositely charged electrodes within the sensing chamber attract the positive and negative ions, setting up a small flow of current in the air space between the electrodes, but when the smoke particles enter the chamber, they attract some of the ions, disrupting the current flow. There is usually a similar chamber constructed so that no smoke particles can enter, so that the smoke detector
constantly compares the current flow in the sensing chamber to the flow in the reference chamber; if a significant difference develops, an alarm is triggered. This is the most commonly used design for domestic smoke detection.

2.1 LDR-BASED SMOKE DETECTOR
LDR (Light Dependent Resistor) also known as a LDR, photo resistor, photoconductor or photocell, is a resistor whose resistance increases or decreases depending on the amount of light intensity. LDRs are usually made of many semi-conductive materials with high resistance. The reason they have a high resistance is that there are very few electrons that are free and able to move because they are held in crystal lattice and are unable to move. When light falls on the semi-conductive material, it absorbs the light photons and the energy is transferred to the electrons, which allow them to break free from the crystal lattice and conduct electricity and lower the resistance of the LDR. In addition to fire and smoke alarms, it finds uses in photographic light meters and street lights.

![Symbol of LDR](symbol.png)

**Figure 1 Symbol of LDR**

This detector relies on the smoke that is produced in the event of a fire and passes between a bulb and an LDR, the amount of light falling on the LDR decreases hence its resistance increases. This in turn affects its voltage characteristics which can be used to pull high the voltage at the base of a transistor to which the supply to the chip on board is completed. The sensitivity of the smoke detector depends on the distance between bulb and LDR. Its working is as illustrated in the figure below.
2.2 PHOTO INTERRUPTER MODULE-BASED SMOKE SENSOR

Photo interrupter comprises of an infrared LED which is called the emitter (E) and a phototransistor called the detector (D). Both devices are housed in the same package so no mechanical adjusting is needed. On the side of the transistor there is a daylight blocking filter to make the photo interrupter less sensitive to ambient light. Apart from usage in smoke alarm, it can be used in controlling the position of a moving part (to check if the part is in desired position or not) or you can count pulses from a rotating index disc to measure the rpm of your motor (rotary encoder).
A photo transistor works like a normal transistor but instead of a current at the base, it requires light to turn on the collector-emitter current flow. In a photo interrupter the LED and the photo transistor are mounted in small posts and when nothing interrupts the beam, the transistor turns on, passing a current from the collector to the emitter. When the beam is interrupted, say, by smoke, the transistor turns off.
A photo interrupter has four leads or connectors: anode and cathode for the LED and collector and emitter for the photo transistor.

A typical connection of the photo interrupter is as shown in the Figure 4.

![Figure 4: Typical photo interrupter circuit](image)

**Figure 6 Typical photo interrupter circuit for digital logic**

In the circuit diagram above, resistor, R1, limits the current to the LED to a typical value of about 20mA. R3 should not be more than 100k as this can lead to additional problems because of the high impedance of the circuit.

Ambient light can cause reaction on the detector. The effect can be reduced by choosing a photo interrupter with the minimum gap width that is possible in the application. When you can’t get rid of ambient light, then the resistors should be adjusted accordingly.

When there is no obstruction in the photo interrupter, the light coming from the LED falls directly onto the photo transistor, this makes the collector terminal to go
ground potential. The output tapped at the collector of the photo transistor reads 0 (LOW)

When there is smoke in the vicinity, it blocks the beam from reaching the photo transistor which in turns reduces its conductivity to ground highly and the output voltage at its collector is 5V(HIGH).

This collector terminal is then connected to the reset control of 555 timer.

Figure 7 Block Diagram for LM 555

The 555 timer is wired as astable multivibrator as shown in the next figure.
With the duty cycle, usually set at 50% for optimum performance, the resistors and capacitor are carefully selected using the following relations:

\[ \text{Duty cycle} = \left(\frac{R_1+R_2}{R_1+2R_2}\right) \times 100\% \]

\[ \text{Frequency, } f = \frac{1.443}{(R_1+2R_2)C} \]

The high voltage at the reset pin enables the ic and it produces square wave continuously through pin3, which in turn drives the speaker or buzzer through a coupling capacitor. The astable is usually configured as an oscillator with a frequency in the audio range (20Hz-20kHz).

### 2.3 RE46C190 PHOTOELECTRIC SMOKE DETECTOR

The RE46C190 is a low voltage, low current programmable photoelectric smoke detector IC. With minimal external components, this smoke detector alarm circuit can provide all the required features for a photoelectric smoke detector type electronic project. Programmable setup, calibration and feature selection are the key to reduced component count and cost. The boost regulator insures proper operation of the infrared diode and the piezo horn under low battery conditions. The design incorporates a gain-selectable photo amplifier for use with an infrared emitter detector pair. An internal oscillator strobes power to the smoke detection circuitry every 10 seconds, to keep the standby current to a minimum. If smoke is sensed, the detection rate is increased to verify an alarm condition. [4]
2.4 SMOKE DETECTOR WITH GAS SENSOR TGS 813

TGS 813 is a general purpose sensor which has good sensitivity characteristics to a wide range of gases including methane, propane, butane and other combustible gases.

It is designed to operate with a stabilized 5V heater supply and a circuit voltage not exceeding 24V. These voltage ratings are very practical when determining the design specifications, which make it highly economical.

The circuit also has a very short initial stabilization time and the relative and elapsed characteristics are very good over a long period of operation. It also has a very low sensitivity to ‘noise gases’ which reduces the problem of nuisance alarming significantly.
Figure 10 TGS 813 configuration [6]

Figure 11 TGS 813 Diagram for Electric Circuit [6]

The TGS 813 is a bulk semiconductor composed mainly of tio dioxide with electrodes and the heater coil located inside the ceramic former.
The variation in resistance of the TGS sensor is measured directly as a change in voltage appearing across the load resistor. In fresh air, the current passing through the sensor and RL in series is steady, but when smoke or combustible gases come into contact with the sensor surface, the sensor resistance decreases in accordance with the concentration of the gas present. The voltage across RL is the same when VC and VH are supplied from AC or DC sources. The output voltage can then be utilized to trigger an alarm.

However, the sensor resistance is dependent upon the ambient temperature and humidity, a phenomenon that will result in fluctuation of the alarming point. Hence, when designing, it is recommended that we determine the mean or average temperature and humidity values in the area of operation, to be able to compensate for seasonal variations in the alarming point. To compensate for this, a negative characteristic thermistor can be used. Another point of consideration is the actual place where the thermistor is placed in the circuit. It shouldn’t be installed near heat dissipating components such as the transformer or the sensor. Also, it should not be installed in position where it is likely to receive a strong wind, as this will also affect the temperature characteristics of the sensor. [6]
2.5 MQ2 SENSOR-BASED SMOKE DETECTOR

The MQ 2 sensor belongs to the MQ series Semiconductor Gas Sensors.

The MQ sensor find application in gas leak and smoke detection application. Their major advantageous features include:

- High sensitivity
- Fast response
- Wide detection range
- Stable performance and long life
- Simple drive circuit

The following table shows the various MQ series sensors and target gas of detection:

<table>
<thead>
<tr>
<th>Model</th>
<th>Target Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>MQ2</td>
<td>General combustible gas including smoke.</td>
</tr>
<tr>
<td>MQ3</td>
<td>Alcohol</td>
</tr>
<tr>
<td>MQ4</td>
<td>Natural gas, Methane</td>
</tr>
<tr>
<td>MQ5</td>
<td>LPG, Natural gas, Coal gas</td>
</tr>
<tr>
<td>MQ6</td>
<td>LPG, Propane</td>
</tr>
<tr>
<td>MQ7</td>
<td>Carbon Monoxide</td>
</tr>
<tr>
<td>MQ8</td>
<td>Hydrogen</td>
</tr>
<tr>
<td>MQ9</td>
<td>CO and Combustible gas</td>
</tr>
<tr>
<td>MQ216</td>
<td>Natural gas\ Coal gas</td>
</tr>
<tr>
<td>MQ306A</td>
<td>LPG, Propane</td>
</tr>
<tr>
<td>MQ309A</td>
<td>CO, Flammable gas</td>
</tr>
<tr>
<td>MQ303A</td>
<td>Alcohol</td>
</tr>
<tr>
<td>MQ131A</td>
<td>Ozone O₃</td>
</tr>
<tr>
<td>MQ135</td>
<td>Air Quality Control(NH3, Benzene, Alcohol, Smoke)</td>
</tr>
<tr>
<td>MQ136</td>
<td>H2S</td>
</tr>
<tr>
<td>MQ137</td>
<td>Ammonia</td>
</tr>
<tr>
<td>MQ138</td>
<td>Mellow, Benzene, Aldehyde, Ketone, Ester</td>
</tr>
</tbody>
</table>

MQ2 is the most suitable and readily available for smoke detection.
MQ2 is a flammable gas and smoke sensor which detects the concentrations of combustible gas in the air and outputs reading as an analog voltage. It is sensitive to a wide range of gases and are used at room temperature. Some modules have a built-in variable resistor to adjust the sensitivity of the sensor.

It falls under the category of electromechanical gas detectors which work by allowing gases to diffuse through a porous membrane to an electrode where it is either chemically oxidized or reduced. The amount of current produced is determined by how much of the gas is oxidized at the electrode, indicating concentration of the gas. However, this type of sensors is subject to corrosive elements or chemical contamination and may last only 1-2 years before a placement is required.

For MQ2, the sensitive material used is SnO₂, whose conductivity is lower in clean air. Its conductivity increases as the concentration of combustible gases increases.
Figure 14 Connection diagram for MQ2 sensor

The output voltage, which is analogue in nature, can be used to activate a buzzer by interfacing it with a microcontroller, Arduino or Raspberry Pi.

For the purpose of design of the smoke detector circuit for this project, the MQ2 sensor was chosen due to the following advantageous features:

✓ Wide detecting scope
✓ Availability
✓ Stable and long life
✓ Fast response
✓ Low cost
✓ Simple drive circuit
CHAPTER 3: REVIEW OF COMPONENTS USED

This chapter focuses on various components and elements that have been used in the project. These include:

1) MQ2 smoke sensor 
2) Atmega 32A 
3) LCD module 
4) Buzzer 
5) LED 
6) Power supply module 

3.1 MQ2 SMOKE SENSOR

MQ2 sensors are used in gas leakage detecting equipment in family and industry, and are suitable for detecting LPG, i-butane, propane, methane, alcohol, Hydrogen, smoke.

3.1.1 Features

- Wide detecting scope
- Fast response and High sensitivity
- Stable and long life
- Simple drive circuit

3.1.2 Specifications

A. Standard work condition

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter name</th>
<th>Technical condition</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_c$</td>
<td>Circuit voltage</td>
<td>5V±0.1</td>
<td>AC OR DC</td>
</tr>
<tr>
<td>$V_H$</td>
<td>Heating voltage</td>
<td>5V±0.1</td>
<td>ACOR DC</td>
</tr>
<tr>
<td>$R_L$</td>
<td>Load resistance</td>
<td>can adjust</td>
<td></td>
</tr>
<tr>
<td>$R_H$</td>
<td>Heater resistance</td>
<td>33Ω±5%</td>
<td>Room Tem</td>
</tr>
<tr>
<td>$P_H$</td>
<td>Heating consumption</td>
<td>less than 800mw</td>
<td></td>
</tr>
</tbody>
</table>

B. Environment condition

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter name</th>
<th>Technical condition</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tao</td>
<td>Using Tem</td>
<td>-20°C-50°C</td>
<td></td>
</tr>
<tr>
<td>Tas</td>
<td>Storage Tem</td>
<td>-20°C-70°C</td>
<td></td>
</tr>
<tr>
<td>$R_H$</td>
<td>Related humidity</td>
<td>less than 95%Rh</td>
<td></td>
</tr>
<tr>
<td>O2</td>
<td>Oxygen concentration</td>
<td>21%(standard condition)</td>
<td>Oxygen concentration can minimum value is over 2%</td>
</tr>
</tbody>
</table>
c. Sensitivity characteristic

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter name</th>
<th>Technical parameter</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rs</td>
<td>Sensing Resistance</td>
<td>3KΩ-30KΩ (1000ppm iso-butane)</td>
<td>Detecting concentration scope: 200ppm-5000ppm LPG and propane 300ppm-5000ppm butane 5000ppm-20000ppm methane 300ppm-5000ppm H&lt;sub&gt;2&lt;/sub&gt; 100ppm-2000ppm Alcohol</td>
</tr>
<tr>
<td>A (3000/1000) isobutane</td>
<td>Concentration Slope rate</td>
<td>≤0.6</td>
<td></td>
</tr>
<tr>
<td>Standard Detecting Condition</td>
<td>Temp: 20°C±2°C  Vc:5V±0.1  Humidity: 65%±5%  Vh: 5V±0.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preheat time</td>
<td>Over 24 hour</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

[7]

D Structure and configuration, basic measuring circuit
Figure 15 Structure of MQ2 [7]

<table>
<thead>
<tr>
<th>Parts</th>
<th>Materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Gas sensing layer</td>
<td>SnO$_2$</td>
</tr>
<tr>
<td>2 Electrode</td>
<td>Au (Gold)</td>
</tr>
<tr>
<td>3 Electrode line</td>
<td>Pt (Platinum)</td>
</tr>
<tr>
<td>4 Heater coil</td>
<td>Nickel-Chromium alloy</td>
</tr>
<tr>
<td>5 Tubular ceramic</td>
<td>Al$_2$O$_3$</td>
</tr>
<tr>
<td>6 Anti-explosion</td>
<td>Stainless steel gauze</td>
</tr>
<tr>
<td>7 Clamp ring</td>
<td>Copper plating, Ni</td>
</tr>
<tr>
<td>8 Resin base</td>
<td>Bakelite</td>
</tr>
<tr>
<td>9 Tube pin</td>
<td>Copper plating, Ni</td>
</tr>
</tbody>
</table>

### 3.1.3 Precautions

**Following conditions must be prohibited**

- Exposure to organic silicon steam
  Organic silicon steam cause sensors invalid. Sensors must be not be exposed to silicon bond, silicon latex, putty or plastic contain silicon environment.

- High Corrosive gas
If the sensors exposed to high concentration corrosive gas (such as H₂Sz, SOₓ, Cl₂, HCl etc), it will not only result in corrosion of sensors structure, also it cause severe sensitivity attenuation.

- Alkali, Alkali metals salt, halogen pollution

The sensors performance will be changed badly if sensors be sprayed polluted by alkali metals salt especially brine, or be exposed to halogen such as fluorine.

- Touch water

Sensitivity of the sensors will be reduced when spattered or dipped in water.

- Freezing

Freezing causes the sensor to lose sensitivity.

- Applied voltage higher

Applied voltage on sensor should not be higher than stipulated value, otherwise it would cause down-line or heater damage, and cause sensors’ sensitivity characteristic alteration.

- Voltage on wrong pins

This would lead to lead breakage, hence damage the functionality of the sensor.

**Following conditions must be avoided**

- Water Condensation

Under indoor conditions, slight water condensation will effect sensors performance lightly. However, if water condensation on sensors surface occurs over a prolonged period, sensor’ sensitivity will be decreased.

- Used in high gas concentration

Whether it is powered or not, prolonged exposure to high gas concentration will affect sensors characteristic adversely.

- Long time storage

The sensors resistance produce reversible drift if it’s stored for long time without powering. For the sensors with long time storage with no powering, they may require aging time for stability before using.

- Long time exposed to adverse environment

Exposure to adverse environment for long time, such as high humidity, high temperature, or high pollution, it will affect the sensors performance adversely.
- **Vibration**

Continual vibration will result in sensors down-lead response then. Transportation or assembling line, pneumatic screwdriver/ultrasonic welding machine can lead this vibration.

- **Concussion**

If sensors meet strong concussion, it may lead its lead wire disconnected.

### 3.2 ATMEGA 32A

Microcontroller is basically a computer on a chip. It is a compact microcomputer, designed to control the operation of embedded electronic systems in various applications such as motor vehicles, home appliances, office machines, robots, medical devices, vending machines, mobile radio transceivers, and other electronic devices. Typically, a microcontroller comprise of a processor, timers, memory, clock/oscillator, and other peripherals. The difference between a microcontroller and a microprocessor is that a microprocessor is an integrated circuit that only has CPU but no memory as in the microcontroller. They are used in general purpose applications.

The Atmel ATmega32A is a low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture. The device is manufactured using Atmel’s high density nonvolatile memory technology.

![Figure 16 ATmega 32A](image)

**Features**
• High-performance, Low-power Atmel AVR 8-bit Microcontroller
• Advanced RISC Architecture

-131 Powerful Instructions - Most Single-clock Cycle Execution
-32 × 8 General Purpose Working Registers
-Fully Static Operation
-Up to 16MIPS Throughput at 16MHz
-On-chip 2-cycle Multiplier
  • High Endurance Non-volatile Memory segments
-32 Kbytes of In-System Self-programmable Flash program memory
-1024 Bytes EEPROM
-2 Kbytes Internal SRAM
-Write/Erase cycles: 10,000 Flash/100,000 EEPROM
-Data retention: 20 years at 85°C/100 years at 25°C(1)
-Optional Boot Code Section with Independent Lock Bits
  • In-System Programming by On-chip Boot Program
  • True Read-While-Write Operation
-Programming Lock for Software Security
  • JTAG Interface
-Boundary-scan Capabilities According to the JTAG Standard
-Extensive On-chip Debug Support
-Programming of Flash, EEPROM, Fuses and Lock Bits through the JTAG Interface
  • Peripheral Features
-Two 8-bit Timer/Counters with Separate Prescalers and Compare Modes
-One 16-bit Timer/Counter with Separate Prescaler, Compare Mode, and Capture Mode
-Real Time Counter with Separate Oscillator
-Four PWM Channels
-8- channel, 10-bit ADC
  - 8 Single-ended Channels
  - 7 Differential Channels in TQFP Package Only
  - Differential Channels with Programmable Gain at 1x, 10x, or 200x
-Byte-oriented Two-wire Serial Interface
-Programmable Serial USART
-Master/Slave SPI Serial Interface
-Programmable Watchdog Timer with On-chip Oscillator
-On-chip Analog Comparator
  - I/O and Packages
-32 Programmable I/O Lines
-40-pin PDIP, 44-lead TQFP, and 44-pad QFN/MLF
  - Operating Voltages
-2.7 - 5.5V
  - Speed Grades
-0 -16MHz
  - Power Consumption at 1MHz, 3V, 25°C
-Active: 0.6mA
-Idle Mode: 0.2mA
-Power-down Mode: < 1μA
Figure 17 Pinout PDIP ATmega 32A [8]

- **VCC**

This is the digital supply voltage.

- **GND**

This is the ground pin.

- **Port A (PA7:PA0)**

Port A serves as the analog inputs to the A/D Converter. Port A also serves as an 8-bit bi-directional I/O port, if the A/D Converter is not used.

- **Port B (PB7:PB0)**

Port B is an 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit).

- **Port C (PC7:PC0)**

Port C is an 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). If the JTAG interface is enabled, the pull-up resistors on pins PC5(TDI), PC3(TMS) and PC2(TCK) will be activated even if a reset occurs.

The TD0 pin is tristated unless TAP states that shift out data are entered.

- **Port D (PD7:PD0)**
Port D is an 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit).

- **RESET**
  
  This is the reset input. A low level on this pin for longer than the minimum pulse length will generate a reset, even if the clock is not running. The minimum pulse length is given in System and Reset Characteristics. Shorter pulses are not guaranteed to generate a reset.

- **XTAL1**
  
  Input to the inverting Oscillator amplifier and input to the internal clock operating circuit.

- **XTAL2**
  
  Output from the inverting Oscillator amplifier.

- **AVCC**
  
  AVCC is the supply voltage pin for Port A and the A/D Converter. It should be externally connected to VCC, even if the ADC is not used. If the ADC is used, it should be connected to VCC through a low-pass filter.

- **AREF**
  
  AREF is the analog reference pin for the A/D Converter.

### 3.3 LCD MODULE

A liquid-crystal display (LCD) is a flat-panel display or other electronic visual display that uses the light-modulating properties of liquid crystals.

The LCD screen is more energy-efficient and can be disposed of more safely than a CRT. Its low electrical power consumption enables it to be used in battery-powered electronic equipment more efficiently than CRTs. It is an electronically modulated optical device made up of any number of segments controlling a layer of liquid crystals and arrayed in front of a light source (backlight) or reflector to produce images in color or monochrome. [9]
The 1602A QAPASS module was used in this project.

### Mechanical Dimension

<table>
<thead>
<tr>
<th>Item</th>
<th>Dimension</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Characters</td>
<td>16 characters x 2 Lines</td>
<td>Š Š</td>
</tr>
<tr>
<td>Module dimension (L x W x H)</td>
<td>80.0 x 36.0 x 12.7 (Max) - LED array B/L, LED edge B/L (white, blue) 80.0 x 36.0 x 8.9 (Max) – LED edge/blue B/L, EL or No B/L</td>
<td>mm</td>
</tr>
<tr>
<td>View area</td>
<td>66.0 x 16.0</td>
<td>mm</td>
</tr>
<tr>
<td>Active area</td>
<td>56.2 x 11.5</td>
<td>mm</td>
</tr>
<tr>
<td>Dot size</td>
<td>0.56 x 0.66</td>
<td>mm</td>
</tr>
<tr>
<td>Dot pitch</td>
<td>0.60 x 0.70</td>
<td>mm</td>
</tr>
<tr>
<td>Character size (L x W)</td>
<td>2.96 x 5.56</td>
<td>mm</td>
</tr>
<tr>
<td>Character pitch (L x W)</td>
<td>3.55 x 5.94</td>
<td>mm</td>
</tr>
</tbody>
</table>

The term liquid crystal is used to describe a substance in a state between liquid and solid but which exhibits the properties of both. Molecules in liquid crystals tend to arrange themselves until they all point in the same specific direction. This
arrangement of molecules enables the medium to flow as a liquid. Depending on the temperature and particular nature of a substance, liquid crystals can exist in one of several distinct phases. Liquid crystals in a nematic phase, in which there is no spatial ordering of the molecules, for example, are used in LCD technology.

One important feature of liquid crystals is the fact that an electrical current affects them. A particular sort of nematic liquid crystal, called twisted nematics (TN), is naturally twisted. Applying an electric current to these liquid crystals will untwist them to varying degrees, depending on the current’s voltage. LCDs use these liquid crystals because they react predictably to electric current in such a way as to control the passage of light.

The working of a simple LCD is shown in the figure below.

![Diagram of LCD components](image)

**Figure**

It has a mirror (A) in back, which makes it reflective. There is a piece of glass (B) with a polarizing film on the bottom side, and a common electrode plane (C) made of indium-tin oxide on top. A common electrode plane covers the entire area of the LCD. Above that is the layer of liquid crystal substance (D). Next comes another piece of glass (E) with an electrode in the shape of the rectangle on the bottom and, on top, another polarizing film (F), at a right angle to the first one.

The electrode is hooked up to a power source like a battery. When there is no current, light entering through the front of the LCD will simply hit the mirror and bounce right back out. But when the battery supplies current to the electrodes, the liquid crystals between the common-plane electrode and the electrode shaped like a rectangle untwist and block the light in that region from passing through. That makes the LCD show the rectangle as a black area.

**Back Lit and Reflective LCDs**

Liquid crystal materials emit no light of their own. Small and inexpensive LCDs are often reflective, which means if they are to display anything, they must reflect the light from external light sources. The numbers in an LCD watch appear where
the small electrodes charge the liquid crystals and make the crystals untwist so that
the light is not transmitting through the polarized film.

Backlit LCD displays are lit with built-in fluorescent tubes above, beside and
sometimes behind the LCD. A white diffusion panel behind the LCD redirects and
scatters the light evenly to ensure a uniform display. On its way through liquid
crystal layers, filters and electrode layers, more than half of this light is lost such as
in LCD displays on personal computers.

In the reflective mode, available light is used to illuminate the display. This is
achieved by combining a reflector with the rear polarizer. It works best in an
outdoor or well-lighted office environment. Transmissive LCDs have a transparent
rear polarizer and do not reflect ambient light. They require a backlight to be
visible. They work best in low-light conditions, with the backlight on continuously.

Transflective LCDs are a mixture of the reflective and transmissive types, with the
rear polarizer having partial reflectivity. They are combined with backlight for use
in all types of lighting conditions. The backlight can be left off where there is
sufficient light, conserving power. In darker environments, the backlight can
provide a bright display.

Transflective LCDs will not “wash out” when operated in direct sunlight. Another
feature of the viewing mode is whether the LCD is a positive or negative image.
The standard image is positive, which means a light background with a dark
character or dot. This works best in reflective or transflective mode. A negative
image is usually combined with a transmissive mode. A strong backlight
must be used to provide good illumination. In most graphic applications, the
transmissive negative mode is inverted. This combination provides a light
background with dark characters, which offers the user better readability.
Threshold voltage and sharpness of the response are important parameters to
characterize the quality of LCDs. The threshold voltage, \( V_{\text{th}} \), is the amount of
voltage across the pixel that is necessary to produce any response whatsoever.
Sharpness' of the response can be calculated by finding the difference in voltage
necessary to go from a 10% to a 90% brightness (usually written as \( V_{90} - V_{10} \)).
Another characteristic of displays that must be dealt with is the switching times of the pixels. These are commonly written as $T_{on}$ and $T_{off}$, and they correspond to the amount of time between application/removal of the voltage and a 90% brightness/darkness response. Usually $T_{off}$ is slightly larger, because after voltage is removed, the liquid crystal relaxes back into its off state. No force is being applied, unlike when it is being turned on. Switching times can be changed by controlling the amount of orientational viscosity in the crystal, which is the amount of resistance when being forced to change direction.

The contrast of a liquid crystal display is an important issue as well. One way to measure it is to find the difference in brightness between an on and off pixel, divided by the larger of the two values. A more useful value is the contrast ratio, which is simply the larger brightness divided by the smaller brightness.

LCD designers want this ratio to be as large as possible in order to obtain "blacker blacks" and "whiter whites." Typical LCDs have contrast ratios between 10 and 40. Unfortunately, the contrast will depend on the angle the display is viewed from since the effects of the liquid crystal are calibrated to work best on light passing through the display perpendicularly. When viewed from an angle, we are not seeing the light coming out perpendicularly from the liquid crystal, so it is common to see a breakdown in the contrast. In some cases it is even possible to see a negative image of the display.

LCDs are available to display arbitrary images (as in a general-purpose computer display) or fixed images with low information content, which can be displayed or hidden, such as preset words, digits, and 7-segment displays as in a digital clock. They use the same basic technology, except that arbitrary images are made up of a large number of small pixels, while other displays have larger elements.

LCDs are used in a wide range of applications including computer monitors, televisions, instrument panels, aircraft cockpit displays, and signage. They are common in consumer devices such as DVD players, gaming devices, clocks, watches, calculators, and telephones, and have replaced cathode ray tube (CRT) displays in nearly all applications. They are available in a wider range of screen sizes than CRT and plasma displays, and since they do not use phosphors, they do not suffer image burn-in. LCDs are, however, susceptible to image persistence. [9]
Types of LCDs

i. Passive Matrix

These LCDs use a simple grid to supply the charge to particular pixels on the display. Passive Matrix LCDs start with two glass layers called the substrates. One substrate is given rows and the other is given the columns, made from a transparent conductive material. The liquid crystal material is sandwiched between the two glass substrates, and the polarizing film is added to the outer side of each display.

To turn on a pixel, the integrated circuit sends a charge down the correct column of one substrate and a ground activated on the correct row of the other. The row and column intersect at a designated pixel, and that delivers the voltage to untwist the liquid crystals at that pixel. As the current required to brighten a pixel increases (for higher brightness displays) and, as the display gets larger, this process becomes more difficult since higher currents have to flow down the control lines. Also, the controlling current must be present whenever the pixel is required to light up. As a result, passive matrix displays tend to be used mainly in applications where inexpensive, simple displays are required.

ii. Active Matrix or TFT (Thin Film Transistor) LCDs

Active matrix displays belong to type of flat-panel display in which the screen is refreshed more frequently than in conventional passive-matrix displays, and which uses individual transistors to control the charges on each cell in the liquid-crystal layer. The most common type of active-matrix display is based on the TFT technology. The two terms, active matrix and TFT, are often used interchangeably. Whereas a passive matrix display uses a simple conductive grid to deliver current to the liquid crystals in the target area, an active matrix display uses a grid of transistors with the ability to hold a charge for a limited period of time, much like a capacitor. Because of the switching action of transistors, only the desired pixel receives a charge, improving image quality over a passive matrix. Because of the thin film transistor’s ability to hold a charge, the pixel remains active until the next refresh.

There are three main switch technologies of TFTs: amorphous silicon (a-Si), polycrystalline silicon (p-Si), and single crystal silicon (x-Si). The silicon transistor matrix in a TFT is typically composed of amorphous silicon (a-Si). Amorphous silicon TFT LCDs have become the standard for mass-produced AMLCDs. They have good color, good greyscale reproduction, and fast response. [10]
3.4 BUZZER
A buzzer is an audio signaling device which may be used in alarm devices, timers and other forms of alerts. They may be mechanical, electromechanical, or piezoelectric.

Figure 19 Buzzer

Electromechanical buzzers use a relay connected to interrupt its own actuating current, causing the contacts to buzz. Mechanical buzzers are purely mechanical and require drivers.

Piezoelectric elements are driven by an oscillating electronic circuit or other audio signal source, driven with a piezoelectric audio amplifier.

For this project, the buzzer used is the compact, pin terminal type electromagnetic buzzer with 2048 Hz output. Pin type terminal construction enables direct mounting onto printed circuit boards.

3.5 LED
A light-emitting diode (LED) is a two-lead semiconductor light source. It is a p–n junction diode, which emits light when activated. When a suitable voltage is applied to the leads, electrons are able to recombine with electron holes within the device, releasing energy in the form of photons. This effect is called electroluminescence, and the color of the light (corresponding to the energy of the photon) is determined by the energy band gap of the semiconductor. [11]

Figure 20 Electronic Symbol for LED
3.6 POWER SUPPLY MODULE

The power supply module was required to supply regulated 5V dc to the circuit while plugged to the mains.

The components include:

- Step down transformer
- Voltage regulator
- Capacitors
- Diodes

3.6.1 Transformer

Selection of a suitable transformer was based on the following factors:

The current required for the load to be driven (1A).

The input voltage to the 7805 IC should be at least 2V greater than the required 5V output, hence it requires an input voltage of at least 7V.

Hence the chosen transformer was a 9-0-9 transformer with current rating of 1A (Since $9 \times \sqrt{2} = 12.73V$).

3.6.2 Rectifying circuit

The best is using a full wave rectifier, it’s advantage being that DC saturation is less as both cycles conduct.

1N4007 diodes are used as it’s capable of withstanding a higher reverse voltage of 1000v whereas 1N4001 is 50V.

3.6.3 Voltage regulator

LM7805 voltage regulator IC was used since we needed 5V.
LM7805 voltage regulator is a voltage regulator that outputs +5 volts.

This IC is a three-pin IC having the Input pin, Ground and Output pin.

The voltage regulator contains reference voltage element (Zener diode), sampling element, error amplifier element and power control element.

It’s ratings are:
- Input voltage range 7V-35V
- Current rating, I_c=1A
- Output voltage range: V_{max}=5.2V, V_{min}=4.8V

3.6.4 Capacitors

The electrolytic capacitor act as smoothening capacitor by charging up with voltage during a spike and discharging to the supply voltage when the supply is low.

To determine the value of the filter capacitor,

Ripple factor, Y=1/\sqrt[4]{3fRC}

R=calculated resistance

C=filtering capacitance

f=frequency of AC(50Hz)

R=V/I_c

V=secondary voltage of transformer=9\sqrt{2}=12.73V

R=12.73/1=12.73Ω

Standard value of resistance choosen=13Ω

Y=(V_{ac}-V_{rms})/V_{dc}

V_{ac}-V_{rms}=V_r/2\sqrt{3}

V_{dc}=V_{max}-V_r/2

V_r=V_{max}-V_{min}=5.2V-4.8V=0.4V

V_{ac}-V_{rms}=0.4/2\sqrt{3}=0.11547V

V_{dc}=5V

Y=0.11547/5=0.02309

C=1/\sqrt[4]{3fRY}=9617uf

Available capacitance=6800uf
Also from the datasheet of LM7805, the module should have capacitors of 0.33uf and 0.1uf at the input and output respectively. These ceramic capacitors serve the purpose of noise suppression by shorting the noise to ground.
CHAPTER 4: DESIGN

The primary objective of this project was to design a circuit that detects smoke and triggers an alarm.

The design of this system has been divided into:

- Hardware design
- Software design
- Fabrication

Figure 22: FLOWCHART FOR PROJECT DESIGN PROCESS
4.1 HARDWARE DESIGN

4.1.1 MQ2 SENSOR

The MQ2 sensor module was selected to serve the purpose of sensing smoke. It has the capability of sensing smoke and other combustible gases. The following are the reasons as to why it was selected:

- Wide detecting scope
- Fast response & high sensitivity
- Stable and long life
- Simple drive circuit

![MQ2 Sensor Image]

Figure 23: MQ2 SENSOR

The sensor can detect smoke in the range of 300-10,000 ppm, giving an analog output voltage of between 0v to 5v depending on the quantity of smoke detected.

The sensitive material used is SnO₂, whose conductivity is lower in clean air. Its conductivity increases as the concentration of combustible gases increases, hence generating a corresponding analog voltage at the output.
4.1.2 ATMEGA 32A
Atmega 32A was selected due to its relatively large flash memory (32kb) as well as availability of many (32) programmable I/O lines.

Table 4.1

<table>
<thead>
<tr>
<th>Pin function</th>
<th>Number of pins</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensor input</td>
<td>1</td>
</tr>
<tr>
<td>LCD data</td>
<td>4</td>
</tr>
<tr>
<td>LCD control</td>
<td>2</td>
</tr>
<tr>
<td>Power</td>
<td>2</td>
</tr>
<tr>
<td>Visual alarms (LEDs)</td>
<td>5</td>
</tr>
<tr>
<td>Audio alarm (buzzer)</td>
<td>1</td>
</tr>
<tr>
<td>Reset pin</td>
<td>1</td>
</tr>
<tr>
<td>AVCC &amp; AREF</td>
<td>2</td>
</tr>
</tbody>
</table>

4.1.3 INTERFACING LCD TO ATMEGA 32A
The purpose of using the LCD was to display the quantity of smoke detected as well as to display the status of the system.

The LCD used was a 16 character by two line display.
The LCD can operate in 4-bit mode or 8-bit mode. The 4-bit mode was selected due to the advantage of greater economy of I/O pins. Hence pins D0, D1, D2 and D3 are connected to ground.

Also, R/W line is connected to ground since data is always written into the LCD.

<table>
<thead>
<tr>
<th>PIN NUMBER</th>
<th>SYMBOL</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$V_{ss}$</td>
<td>Ground</td>
</tr>
<tr>
<td>2</td>
<td>$V_{dd}$</td>
<td>Power supply+ 5V</td>
</tr>
<tr>
<td>3</td>
<td>Vo</td>
<td>Contrast Control</td>
</tr>
</tbody>
</table>
| 4          | RS     | Set/reset  
0 = instruction input  
1 = data input |
| 5          | R/W    | R/W (read/write select)  
0 = write to LCD  
1 = read LCD data |
| 6          | E      | Enable. Clock signal to initiate data transfer |
| 7          | D0     | Data bus line 0 |
| 8          | D1     | Data bus line 1 |
| 9          | D2     | Data bus line 2 |
| 10         | D3     | Data bus line 3 |
| 11         | D4     | Data bus line 4 |
| 12         | D5     | Data bus line 5 |
| 13         | D6     | Data bus line 6 |
| 14         | D7     | Data bus line 7 |
4.1.4 VISUAL ALARM (LEDs)

LEDs were used for the sole purpose of visual alert. One green LED was set to be lit when there was no significant smoke detected in the environment. In the event that smoke is detected, the green LED was set to go off. Four red were set to be off when there was no smoke detected and to blink in the event smoke is detected in the environment.

A current limiting resistance was required for each of the LED. With a Vcc of 5v, the mcu could give a maximum of 5v while the LED needs 20mA in order to light and a forward voltage of 1.8-3.3V. From Ohm’s Law, \( R = \frac{V - V_f}{I_s} \).

\[ R = \frac{5 - 1.8}{20/1000} = 160\Omega \]

In order to ensure the current sourced is as little as possible, 220\( \Omega \) resistor was chosen for current limiting, such that the maximum current sourced became;

\[ \frac{5.0V - 1.8V}{220\Omega} = 15mA \]
4.1.5 AUDIO ALARM (BUZZER)

A pin type electromagnetic buzzer was selected due to its ease in mounting to printed circuit board as well as the sound output frequency of 2048Hz which is audible to most people. Its operating voltage was 3-6v and a maximum current of 60mA.

The buzzer was set to be off when there was no significant amount of smoke detected in the environment and to be activated when smoke was detected.

It was connected to pin PB0 of the microcontroller.

The final designed circuit was as shown in the next figure:
Figure 27 Final design of smoke sensor (Excluding the power supply)
4.2 SOFTWARE DESIGN

For the microcontroller to interface the sensor and the alarms and the LCD, it had to be programmed, hence necessitating software design. The following flowchart indicates the functionality of the circuit and was used as a guide in the software design.

Figure 28 FLOWCHART FOR SOFTWARE DESIGN
The software design was divided into the following sections:

- ADC program
- LCD program
- Alarm activation program
- Main program

4.2.1 ADC PROGRAM

This was necessitated by the fact that the MQ2 sensor gives an output voltage which is analogous to the quantity of smoke detected.

The purpose was to convert the analog voltage to a digital number since the microcontroller is digital.

Atmega 32A has an inbuilt Analog to Digital Converter, with PORTA containing the ADC pins. The ADC has 10-bit resolution, which implies that there are $2^{10}=1024$ steps. The type of ADC inside the microcontroller is of successive approximation type.

It has 8 channels, which implies that there are 8ADC pins (PA0…PA7) which are multiplexed together.

**Initializing The ADC program**

The ADC Multiplexer Selection Register (ADMUX) has 8 registers.

Registers REFS1 & REFS0 form bits 7 and 6 respectively in ADMUX and are used to choose the reference voltage. The following combinations maybe used:

<table>
<thead>
<tr>
<th>REFS1</th>
<th>REFS0</th>
<th>Voltage Reference Selection</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>AREF, Internal Vref turned off</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>AVCC and AREF pin</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>Reserved</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>Internal 2.56V Voltage Reference</td>
</tr>
</tbody>
</table>

Since the Vcc (+5v) was to be used as reference, the second option was chosen.

Thus, to initialize ADMUX, the following line of code was written:

```
ADMUX = (1 << REFS0);
```

**Setting the Prescaler**

The ADC Control and Status Register A has the following 8 bits:

Bit 7-ADC Enable (ADEN): Unless it’s enabled, ADC operations cannot take place across PORTA.
Bit 6-ADC Start Conversion (ADSC): This has to be written to ‘1’ before starting any conversion.

Bit 5-ADC Auto Trigger Enable (ADATE): Setting it to ‘1’ enables auto-triggering of ADC. ADC is triggered automatically at every rising edge of clock pulse.

Bit 4-ADC Interrupt Flag (ADIF): Used to check whether the conversion is complete or not. Whenever a conversion is finished and the registers are updated, this bit is set to ‘1’ automatically.

Bit 3-ADC Interrupt Enable (ADIE): When set to ‘1’, the ADC interrupt is enabled.

Bit 2:0-ADC Prescaler Select Bits (ADPS2:0): The prescaler (division factor between the mcu frequency and ADC frequency) is determined by selecting the proper combination from the following.

<table>
<thead>
<tr>
<th>ADPS2</th>
<th>ADPS1</th>
<th>ADPS0</th>
<th>Division Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>16</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>1</td>
<td>32</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>0</td>
<td>64</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>128</td>
</tr>
</tbody>
</table>

A prescaler of 8 was chosen. Thus, F_ADC=1M/8=125 kHz

Hence, ADCSRA was initialized as follows:

```c
ADCSRA = (1<<ADEN)|(1<<ADPS1)|(1<<ADPS0);
```

**Reading ADC value**

```c
uint16_t adc_read(uint8_t ch)
{
  // select the corresponding channel 0~7
  // ANDing with '7' will always keep the value
  // of 'ch' between 0 and 7
  ch &= 0b00000111; // AND operation with 7
  ADMUX = (ADMUX & 0xF8)|ch; // clears the bottom 3 bits before ORing
  // start single conversion
  // write '1' to ADSC
  ADCSRA |= (1<<ADSC);
  // wait for conversion to complete
  // ADSC becomes '0' again
  // till then, run loop continuously
  while(ADCSRA & (1<<ADSC));
  return (ADC);
}
```
4.2.2 LCD PROGRAM

The LCD was implemented in the 4-bit mode as opposed to the 8-bit mode. In this method, we are splitting Bytes of data in Nibbles. The advantage of using the 4-bit mode is the utilization of fewer pins for interfacing with the microcontroller. However, in the 4-bit mode, data must be sent one nibble at a time, so execution time is twice that of 8-bit mode.

Displaying data using a 4-bit interface consists of sending the high-order nibble followed by the lower-order nibble through the LCD 4-high-order-data lines. The pulsing of the E-line follows the last nibble sent. Software must provide a way of reading and writing to the appropriate port lines, the ones used in data transfer, without altering the value stored in the port bits dedicated to other uses.

The R/W pin is always low since data is always written into the LCD. The RS pin was connected to PD0 and was used to control the instructions or characters sent to the LCD. The Enable pin was connected to PD1 and it was used to enable the LCD to either feed instruction into the register or write character into it.

4.2.3 ALARM ACTIVATION PROGRAM

When the smoke detected exceeds the rated value, the buzzer is activated, the green LED is switched off and the red LEDs are switched on in addition to the status indication of ‘smoke detected’ on the LCD. As long as the circuit is powered, the sensor keeps checking for the presence of smoke.

For the purpose of demonstration, the preset value was 3800 particles per million (ppm).

The following section of the code was responsible for alarm activation:

```c
if(adc_result0>380){
    PORTB = 0x01; //Simultaneously switching on the buzzer and green LED off.
    PORTB ^= (1<<1); //Blinking the four red LEDs.
    PORTB ^= (1<<2); 
    PORTB ^= (1<<3);
    PORTB ^= (1<<4);
    _delay_ms(1);
    PORTB ^= (1<<1);
    PORTB ^= (1<<2);
    PORTB ^= (1<<3);
    PORTB ^= (1<<4);
}
else{
    PORTB &~=(1<<1); //Switching off the red LEDs
    PORTB &~=(1<<2);
    PORTB &~=(1<<3);
    PORTB &~=(1<<4);
    PORTB = 0x20; //Switching on the green LEDs and switching off the buzzer
}
```
4.3 PCB DESIGN

The circuit was first tested on a breadboard and found to be functioning and the next step was fabrication. This was to facilitate to fit the whole design on a small board and in a compact manner. It also helps in improving the organization of the whole design as well make it neat and presentable.

The first step involved drawing the whole layout on proteus software to determine how the components will be arranged on the board before replicating the same on the PCB.

The layout of copper wires was drawn on express PCB.

The drawing was then printed on a transparent paper, before the paper was laid on the PCB board and UV lights passed on them. The copper lines soften the material except the copper lines.

It was then passed through a developing solution of Sodium Hydroxide where only the needed copper lines were outlined.

The next step involved the etching process where the weakened copper was removed from the board, leaving only the needed copper lines.

The final step involved drilling of holes for the needed components, and soldering of components onto the board.
CHAPTER 5: RESULTS

5.1 SIMULATED RESULTS

The following results have been obtained after simulation on Proteus software. Since the smoke sensor gives an output of analog voltage, it was simulated by giving a corresponding voltage to the input of the microcontroller which was to be connected to the sensor.

<table>
<thead>
<tr>
<th>Sensor output</th>
<th>Equivalent smoke quantity</th>
<th>State of GREEN LED</th>
<th>State of RED LED</th>
<th>State of buzzer</th>
<th>LCD display</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00V</td>
<td>0ppm</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>STANDBY MODE</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>QTY=0ppm</td>
</tr>
<tr>
<td>0.50V</td>
<td>1020ppm</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>STANDBY MODE</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>QTY=1020ppm</td>
</tr>
<tr>
<td>1.00V</td>
<td>2050ppm</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>STANDBY MODE</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>QTY=2050ppm</td>
</tr>
<tr>
<td>1.50V</td>
<td>3070ppm</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>STANDBY MODE</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>QTY=3070ppm</td>
</tr>
<tr>
<td>1.70V</td>
<td>3480ppm</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>STANDBY MODE</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>QTY=3480ppm</td>
</tr>
<tr>
<td>1.80V</td>
<td>3690ppm</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>STANDBY MODE</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>QTY=3690ppm</td>
</tr>
<tr>
<td>1.84V</td>
<td>3770ppm</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>STANDBY MODE</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>QTY=3770ppm</td>
</tr>
<tr>
<td>1.86V</td>
<td>3810ppm</td>
<td>OFF</td>
<td>Flashing</td>
<td>ON</td>
<td>SMOKE DETECTED</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>QTY=3810ppm</td>
</tr>
<tr>
<td>1.90V</td>
<td>3890ppm</td>
<td>OFF</td>
<td>Flashing</td>
<td>ON</td>
<td>SMOKE DETECTED</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>QTY=3890ppm</td>
</tr>
<tr>
<td>2.00V</td>
<td>4100ppm</td>
<td>OFF</td>
<td>Flashing</td>
<td>ON</td>
<td>SMOKE DETECTED</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>QTY=4100ppm</td>
</tr>
<tr>
<td>2.50V</td>
<td>5120ppm</td>
<td>OFF</td>
<td>Flashing</td>
<td>ON</td>
<td>SMOKE DETECTED</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>QTY=5120ppm</td>
</tr>
<tr>
<td>3.00V</td>
<td>6140ppm</td>
<td>OFF</td>
<td>Flashing</td>
<td>ON</td>
<td>SMOKE DETECTED</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>QTY=6140ppm</td>
</tr>
<tr>
<td>3.50V</td>
<td>7170ppm</td>
<td>OFF</td>
<td>Flashing</td>
<td>ON</td>
<td>SMOKE DETECTED</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>QTY=7170ppm</td>
</tr>
<tr>
<td>4.00V</td>
<td>8190ppm</td>
<td>OFF</td>
<td>Flashing</td>
<td>ON</td>
<td>SMOKE DETECTED</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>QTY=8190ppm</td>
</tr>
<tr>
<td>4.50V</td>
<td>9220ppm</td>
<td>OFF</td>
<td>Flashing</td>
<td>ON</td>
<td>SMOKE DETECTED</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>QTY=9220ppm</td>
</tr>
</tbody>
</table>
Figure 29: LCD DISPLAY IN SMOKE DETECTED MODE SIMULATION
The critical value for smoke detection was 3800ppm. It was a preset value and could be altered in the code.

From the simulated results, it was observed that the immediately the smoke quantity was greater than the pre-set value of 3800ppm, the audio and visual alarms were triggered accordingly.

From the observations, the system achieves the functionality of a smoke detector device.
5.3 RESULTS AFTER IMPLEMENTATION

The above diagram shows the final circuit after fabrication, but with the power supply switched off. As expected, all the LEDs, buzzer and LCD were off regardless of the environmental smoke conditions.
The above image was taken while the circuit was being tested while mounted on a breadboard. The preset critical value was 3800 ppm but the smoke detected was 3770 ppm hence it had not met the threshold for triggering an alarm. The buzzer and red LEDs were off, while the green LED was on, as expected. The LCD display indicated ‘standby mode’, which was an indicator of insignificant quantity of smoke.
The above image was taken after fabrication. The preset critical value was 3800ppm but the smoke detected was 1230ppm hence it had not met the threshold for triggering an alarm. The buzzer and red LEDs were off, while the green LED was on, as expected. The LCD display indicated ‘standby mode’, which was an indicator of insignificant quantity of smoke.
The above image was taken while the circuit was being tested on the breadboard and in a smoky environment. The red LEDs were blinking, the buzzer was activated and the LCD display indicated ‘SMOKE DETECTED’ and a quantity of 4810ppm. This was as expected since the quantity of smoke had surpassed the preset value of 3800ppm.
The above image was taken after the circuit was fabricated and in a smoky environment. The red LEDs were blinking, the green LED was off, the buzzer was activated and the LCD display indicated ‘SMOKE DETECTED’ and a quantity of 5390ppm. This was as expected since the quantity of smoke had surpassed the preset value of 3800ppm.

All the aforementioned observations were in accordance with the design specifications for the project. The only major limitation while taking the observations is the positioning of the sensor and the direction of the wind since detection would not occur unless the MQ2 sensor comes directly in contact with the smoke particles.

The LCD display also indicates the quantity of smoke upto 10000ppm, since that is the only range within which the sensor operates linearly.
CHAPTER 6: CONCLUSION AND RECOMMENDATION

6.1 CONCLUSION

The main objective of this project has been to design a circuit that detects smoke and consequently triggers an alarm. This objective was met since the system works effectively.

As the smoke detected in the environment varied, the LCD displayed the quantity constantly in particles per million (ppm).

With the smoke below the preset critical value, the green LED was on and the red LEDs were off and the LCD displayed ‘STANDBY MODE’. With the smoke detected above the preset critical value, the green LED was off while the red LEDs were flashing and the LCD displayed ‘SMOKE DETECTED’.

This system can be of great in domestic as well as industrial settings to detect smoke and alert people on an impending fire since smoke is a precursor for fire, instead of relying on heat/temperature sensors which sounds alarm when the fire has already started. This can go a long way in helping to save human life. This system can also be used to detect and deter smokers in areas where smoking is prohibited.

The cost of implementing this system is relatively low since the components used are relatively cheap and are easily available in the market. The single microcontroller can be used to interface several sensors with alarms located in different locations as long as more pins are freed for multiple inputs multiple outputs.

This system comes with a power supply that can be directly plugged to the mains (240V AC) source and give the appropriate operating voltage.
6.2 RECOMMENDATIONS

Human safety is a very crucial aspect in both domestic and industrial setting, hence use of smoke sensors is inevitable in addition to other more sophisticated security systems.

This system should be placed in a cool and dry place in order to ensure a longer life span. It should also be placed in a high place in the room and in the direction of the window where there is most likely to be the direction of the wind to facilitate the contact of the sensor with the smoke. The visual alarms should be positioned a few meters above the ground on an easily visible place. The audio alarm should be as well positioned in a place that its alarm can be easily heard.

Lastly, the method of relaying the alarm remotely has not been explored in this project due to time constraint. GSM and GPS modules can be employed in this case to automatically send a message to a control room to notify operator on the presence of smoke and the exact location of smoke.
References


[2] J. Milke, "History of Smoke Detection: A profile of how the technology and role of smoke detection has changed".


[12] "jenswilly.dk/tag/photointerrupter/," [Online].


APPENDIX 3: C PROGRAM

/*
 *
* Created: 3/29/2016 12:25:41 PM
* Author: NG’ANG’A RENSON NGOCHI
* F17/1421/2011
*/

/*PROJECT 107-SMOKE DETECTOR
 *
 */

#ifndef F_CPU
#define F_CPU 1000000UL // 1 MHz clock speed
#endif
#define D4 eS_PORTD4
#define D5 eS_PORTD5
#define D6 eS_PORTD6
#define D7 eS_PORTD7
#define RS eS_PORTD0
#define EN eS_PORTD1

#include <avr/io.h>
#include <util/delay.h>
#include "lcd.h"

uint16_t adc_result0;

void adc_init(){
    // AREF = AVcc
    ADMUX = (1<<REFS0);
    // ADC Enable and prescaler of 8
    // 1000000/8 = 125000.
    ADCSRA = (1<<ADEN)|(1<<ADPS1)|(1<<ADPS0);
}

uint16_t adc_read(uint8_t ch){
    // select the corresponding channel 0~7
    // ANDing with ’7? will always keep the value
    // of ‘ch’ between 0 and 7
    ch &= 0b00000111; // AND operation with 7
    ADMUX = (ADMUX & 0xF8)|ch; // clears the bottom 3 bits before ORing
    // start single conversion
    // write ’1? to ADSC
    ADCSRA |= (1<<ADSC);
    // wait for conversion to complete
    // ADSC becomes ’0’ again
    // till then, run loop continuously
    while(ADCSRA & (1<<ADSC));
    return (ADC);
}

int main(void) {
    MCUCSR=(1<<JTD);
MCUCSR=(1<<JTD); // temporarily disabling JTAG
_delay_ms(10);

DDRD = 0xFF;
DDRA = 0x00;
DDRC = 0xFF;
DDRB = 0x3F;
PORTB &=~(1<<1);
PORTB &=~(1<<2);
PORTB &=~(1<<3);
PORTB &=~(1<<4);
PORTB &=~(1<<5);

Lcd_Init();
adc_init();

Lcd_Set_Cursor(1,1);
Lcd_Write_String(" WELCOME");
_delay_ms(200);
Lcd_Clear();

Lcd_Set_Cursor(1,1);
Lcd_Write_String("RENSON PROJECT");
Lcd_Set_Cursor(2,1);
Lcd_Write_String("F17/1421/2011");
_delay_ms(200);
Lcd_Clear();

while(1){
    adc_result0 = adc_read(0); // read adc value at PA0
    char display[20] = "QTY= ";
    char countstr[6];

    snprintf(countstr,6,"%d",adc_result0*10);
    strcat(display,countstr);
    strcat(display," ppm");

    if(adc_result0>380){
        PORTB = 0x01; // simultaneously switching on the buzzer and green LED off.
        PORTB ^= (1<<1); // Blinking the four red LEDs.
        PORTB ^= (1<<2);
        PORTB ^= (1<<3);
        PORTB ^= (1<<4);
        _delay_ms(1);
        PORTB ^= (1<<1);
    }
PORTB ^= (1<<2);
PORTB ^= (1<<3);
PORTB ^= (1<<4);
Lcd_Set_Cursor(1,1);
Lcd_Write_String("SMOKE DETECTED");
Lcd_Set_Cursor(2,1);
Lcd_Write_String(display);
}

else{
    PORTB &=(1<<1); //Switching off the red LEDs
    PORTB &=(1<<2);
    PORTB &=(1<<3);
    PORTB &=(1<<4);
    PORTB = 0x20; //Switching on the green LEDs and switching off the buzzer

    Lcd_Set_Cursor(1,1);
    Lcd_Write_String("STANDBY MODE");
    Lcd_Set_Cursor(2,1);
    strcat(display," ");
    Lcd_Write_String(display);
}
}
# APPENDIX 4: COST

<table>
<thead>
<tr>
<th>Component</th>
<th>Quantity</th>
<th>Unit Cost (KSh)</th>
<th>Total Cost (KSh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MQ2 sensor</td>
<td>1</td>
<td>700</td>
<td>700</td>
</tr>
<tr>
<td>Atmega 32A</td>
<td>1</td>
<td>450</td>
<td>450</td>
</tr>
<tr>
<td>LCD</td>
<td>1</td>
<td>400</td>
<td>400</td>
</tr>
<tr>
<td>Buzzer</td>
<td>1</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>LED</td>
<td>5</td>
<td>5</td>
<td>25</td>
</tr>
<tr>
<td>Resistor</td>
<td>7</td>
<td>3</td>
<td>21</td>
</tr>
<tr>
<td>Potentiometer</td>
<td>1</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Switches</td>
<td>3</td>
<td>20</td>
<td>60</td>
</tr>
<tr>
<td>PCB board</td>
<td>1</td>
<td>600</td>
<td>600</td>
</tr>
<tr>
<td>Transformer</td>
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</tr>
<tr>
<td>Diode</td>
<td>2</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>Electrolytic capacitor</td>
<td>2</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>Polyester capacitors</td>
<td>2</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>Voltage regulator (LM 7805)</td>
<td>1</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Breadboard</td>
<td>1</td>
<td>250</td>
<td>250</td>
</tr>
<tr>
<td>Connecting Wires</td>
<td>-</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td><strong>TOTAL COST</strong></td>
<td></td>
<td></td>
<td><strong>3306</strong></td>
</tr>
</tbody>
</table>